

The Tale of 2 ECMO Patients' Journey to Heart Transplant



Karen Rubio MLS (ASCP)
Lead Medical Laboratory Scientist

HAABB 2013



Follow 2 ECMO patients

- Patient #1: < 4 months old
 - Thrombus in left Coronary Artery and Aorta
 - Post surgical removal of thrombus and atrial septectomy with low cardiac output syndrome
 - Respiratory Failure
 - Cardiac Insufficiency
 - Acute Renal Failure
 - Post Op Thrombocytopenia
- Patient #2: >4 months old
 - Dilated Cardiomyopathy
 - Presumed Myocarditis
 - Cardiogenic Shock
 - Rhinovirus



ECPR VS. ECMO

ECPR

- Extracorporeal CardioPulmonary Resuscitation.
 - 1st reported 1992*
- Emergent: mainly for inpatients unresponsive to traditional CPR.
 - Limited to witnessed in-hospital arrest
- Goal: resuscitation and reduce reperfusion injury
 - Can be bloodless if greater than 10 kg patient, cold, low calcium prime with delayed oxygen administration
 - Same pump as ECMO machine, more describes technique used
 - 48 to 72 hours of this technique then patient is rewarmed but may remain on ECMO

ECMO

- ExtraCorporeal Membrane Oxygenation
 - In 1970, Baffes et al reported the successful use of extracorporeal membrane oxygenation as support in infants with congenital heart defects who were undergoing cardiac surgery.¹
 - In 1975, Bartlett et al were the first to successfully use ECMO in neonates with severe respiratory distress.²
 - CMH started ECMO in 1987
 - Urgent:
 - Goal: long-term cardiopulmonary support while the underlying process is treated.
 - Blood prime, normalized calcium, K+, glucose, and pH
 - Average time is approximately 5 days

1. Baffes TG, Fridman JL, Bicoff JP, Whitehill JL. Extracorporeal circulation for support of palliative cardiac surgery in infants. *Ann Thorac Surg.* Oct 1970;10(4):354-63.

2. Bartlett RH, Gazzaniga AB, Jefferies MR, et al. Extracorporeal membrane oxygenation (ECMO) cardiopulmonary support in infancy. *Trans Am Soc Artif Intern Organs.* 1976;22:80-93.



*Del Nido, *Circulation* 1992



Children's Mercy
HOSPITALS & CLINICS
Kansas City

ECMO patient selection criteria

- Acceptable risk/benefit ratio
 - >2000grams, full term
- Reversible pathophysiology
 - <7 days mechanical ventilation, no known lethal congenital anomalies, absence of severe acidosis/hypoxia with multi-system organ failure
- Likelihood of death without ECMO
 - Maxed out medical management and deteriorating
- Consensus
 - Doctors, nurses, and parents



Top 4 list of diagnosis for neonatal ECMO

- Congenital Diaphragmatic Hernia
- Sepsis/Pneumonia
- Respiratory Distress Syndrome (RDS)/Persistent Pulmonary Hypertension of the newborn(PPHN)
- Congenital Heart Disease



Top 4 Pediatric diagnosis for ECMO

- Bacterial and/or Viral pneumonia
- Aspiration pneumonia
- Acute Respiratory Failure
- Cardiac



Typical Orders

Greater than 4 months old


- 2 Units of crossmatched ABO identical are ideal if current Type and Screen is in the TSL.
- With 1 Unit of matching FFP
- Order fresh unit of Platelet pheresis
- Emergency: 2 units O negative RBC's with 1 unit AB FFP (time permitting) with Emergency form or even transfusion free if ECPR is being followed

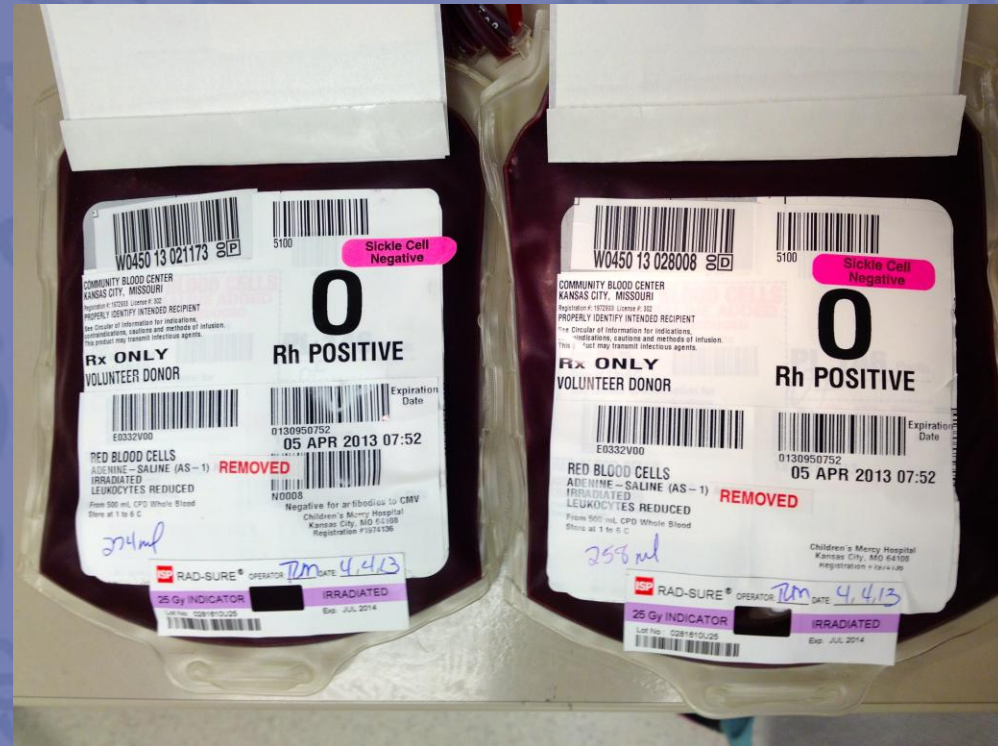
Less than 4 months old

- 1 unit ABO Rh compatible RBCs (type specific non "O" would need crossmatching in IgG)
 - All RBC's are A.F.I.S. prepared for this age group
 - Crossmatched type specific would be readily available if it is a large cardiac case.
- 80 mL of thawed ABO compatible or matched plasma
- Platelets are ordered stat
- Emergency: 1 unit O negative RBC's and 80 mL AB FFP



RBC selection

- A.F.I.S. isn't the FBI's acronym for (Automated Fingerprint Identification System) at CMH 
- Additive AS is removed
- Fresh (less than 7 days old)
- Irradiated
- Sickle cell screened negative



Special thanks to Tonya Moala for preparing the units for their photograph

RBC additives

AABB technical manual recommends caution when neonates are transfused with large volumes of AS components

- Adenine – Renal toxic
- Mannitol – potential diuretic
 - effects of fluid dynamics changes in fluctuations in cerebral blood flow
- Dextrose – High blood glucose – Brain injury
- High potassium – cardiac risk

Perfusions Solution: wash the product with a bag of plasmalyte to neutralize Na⁺ and pH by adding bicarb solution

Table 8-4. Biochemical Changes in Stored Non-Leukocyte-Reduced Red Blood Cells

Variable	CPD		CPDA-1				AS-1	AS-3	AS-5
	Whole Blood		Whole Blood	Red Blood Cells	Whole Blood	Red Blood Cells	Red Blood Cells	Red Blood Cells	Red Blood Cells
Days of Storage	0	21	0	0	35	35	42	42	42
% Viable cells (24 hours posttransfusion)	100	80	100	100	79	71	76 (64-85)	84	80
pH (measure at 37 C)	7.20	6.84	7.60	7.55	6.98	6.71	6.6	6.5	6.5
ATP (% of initial value)	100	86	100	100	56 (± 16)	45 (± 12)	60	59	68.5
2,3-DPG (% of initial value)	100	44	100	100	<10	<10	<5	<10	<5
Plasma K ⁺ (mmol/L)	3.9	21	4.20	5.10	27.30	78.50*	50	46	45.6
Plasma hemoglobin	17	191	82	78	461	658.0*	N/A	386	N/A
% Hemolysis	N/A	N/A	N/A	N/A	N/A	N/A	0.5	0.9	0.6

*Values for plasma hemoglobin and potassium concentrations may appear somewhat high in 35-day stored RBC units; the total plasma in these units is only about 70 mL.

TABLE 6-4. Content of Additive Solutions (mg/100 mL)

Constituent	AS-1 (Adsol)	AS-3 (Nutricel)	AS-5 (Optisol)
Dextrose	2200	1100	900
Adenine	27	30	30
Monobasic sodium phosphate	0	276	0
Mannitol	750	0	525
Sodium chloride	900	410	877
Sodium citrate	0	588	0
Citric acid	0	42	0



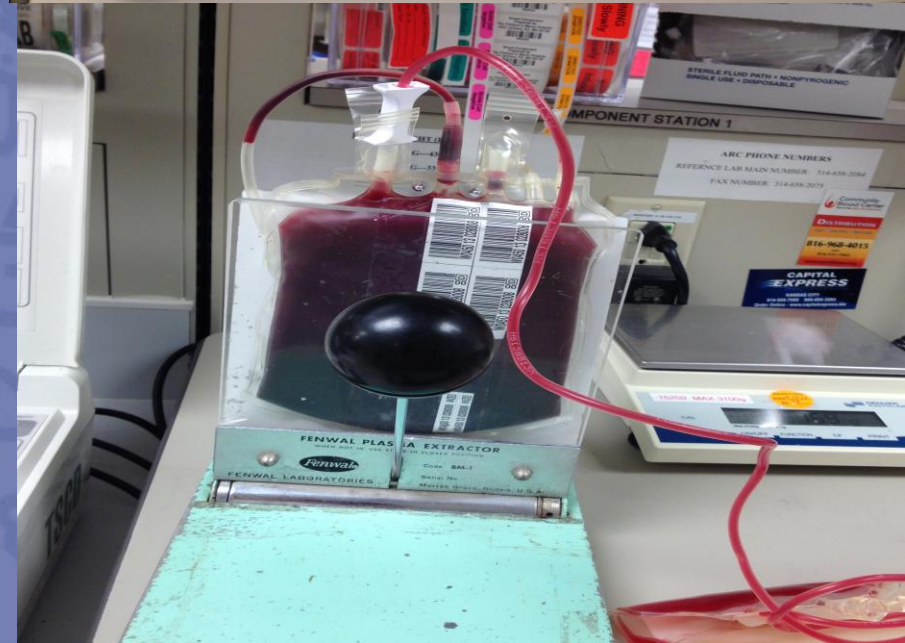
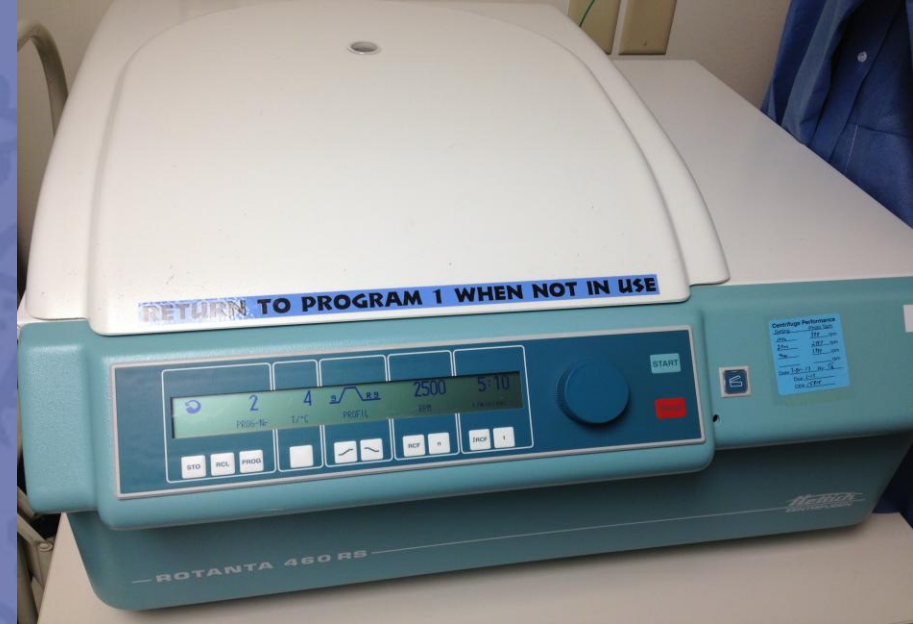
Example Blood Gas results

PRBC unit		pump prime		patient. Arteria	
Patient Sample Report		Patient Sample Report		Patient Sample Report DUPLICATE	
Patient		Patient		Patient	
ID:	PRBC	ID:	PP	ID:	1287182
Status:	NOT VALIDATED	Status:	ACCEPTED	Status:	ACCEPTED
Analyzed:	02/28/2013 09:36:04	Analyzed:	02/28/2013 10:19:02	Analyzed:	02/28/2013 10:16:36
Sample Type:	Other	Sample Type:	Other	Sample Type:	Arterial
Analyzer		Analyzer		Analyzer	
Model:	GEM® Premier 4000	Model:	GEM® Premier 4000	Model:	GEM® Premier 4000
Area:	Area	Area:	Area	Area:	Area
Name:	GP4000	Name:	GP4000	Name:	GP4000
S/N:	10043537	S/N:	10043537	S/N:	10043553
Measured (37.0°C)		Measured (37.0°C)		Measured (37.0°C)	
pH	< 6.80	pH	7.49	pH	7.41
pCO ₂	89 mmHg	pCO ₂	32 mmHg	pCO ₂	38 mmHg
pO ₂	42 mmHg	pO ₂	155 mmHg	pO ₂	89 mmHg
Na ⁺	135 mmol/L	Na ⁺	128 mmol/L	Na ⁺	137 mmol/L
K ⁺	11.7 mmol/L	K ⁺	2.4 mmol/L	K ⁺	↓ 3.2 mmol/L
Cl ⁻	98 mmol/L	Cl ⁻	82 mmol/L	Cl ⁻	107 mmol/L
Ca ⁺⁺	incalculable	Ca ⁺⁺	incalculable	Ca ⁺⁺	1.20 mmol/L
Hct	56 %	Hct	48 %	Hct	↓ 28 %
Glu	> 750 mg/dL	Glu	34 mg/dL	Glu	99 mg/dL
Lac	7.4 mmol/L	Lac	0.9 mmol/L	Lac	0.7 mmol/L
				CO-Oximetry	



AS removal

- Spin 1 or 2 RBC units at 2500 RPM for 10 minutes
- Remove all visible additive and plasma
- End volume is typically 230 to 280 mL



Fresh less than 7 days old

- Extra cellular potassium leaking out of the stored RBC
- Usually not a problem if given in routine transfusion
- Doesn't hold true in large volume situations like ECMO especially in neonates



Irradiated

- An infant's immature immune system predisposes it to infectious and noninfectious serious hazards of transfusion
- Most of the special processing and manipulation of products (the cool stuff) is directly related to their underdeveloped immune function
- The lack of red cell alloantibody production during this period isn't well understood.
 - could be attributed to deficient T-helper function, enhanced T-suppressor activity, and poor antigen-presenting cell function
- Cellular immune responses are also incompletely developed during this period and may make the infant susceptible to transfusion associated graft-vs-host disease
 - Neonates with TA-GVHD present clinically following prolonged latent period, with fever occurring at an average of 28 days after exposure
 - 90% fatal



Sickle cell screen tested

- Performed on donor units used in neonatal transfusions (less than 4 month of age)
- Sickle trait donors still have a small percentage of sickle cells
- Under stress cells will sickle
- Not ideal in large volume situations



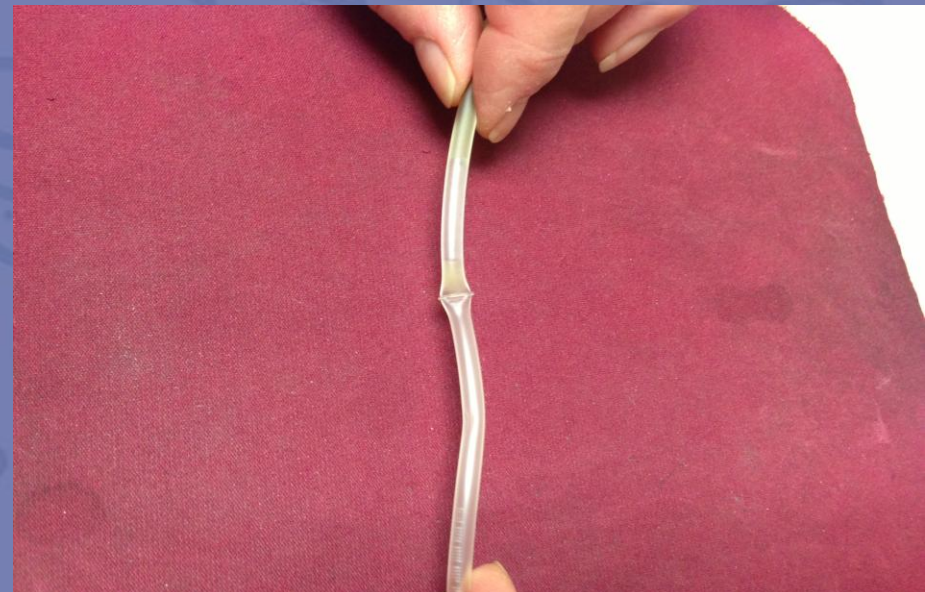
Maintenance

- 24 hour order for RBC and Platelet
- Criterion for each parameter monitored through repeat lab tests
 - CBC & Platelet count q 6 hr
 - ACT q 1 hr to monitor heparin infusion
 - Fibrinogen - >150
 - Lytes q 12 hr anion gap used to evaluate perfusion state
 - Glucose q 4 hr
 - Decreasing Na⁺ requirements and increasing K⁺ requirements
 - Calcium frequently with cardiac patients or with a lot of transfusions
 - NPO – only TPN
- In neonates this can translate into multiple manipulations of the same blood product to make small enough volumes for repeat transfusions of RBCs and more commonly...



Platelets!!!

Especially for neonates we strive to obtain fresh ABO and Rh specific. We use SCD techniques to maintain bag sterility. One of our great “go go gadget” toys.



Special thanks to Lauren Parsons for her photography

The ECMO Machine

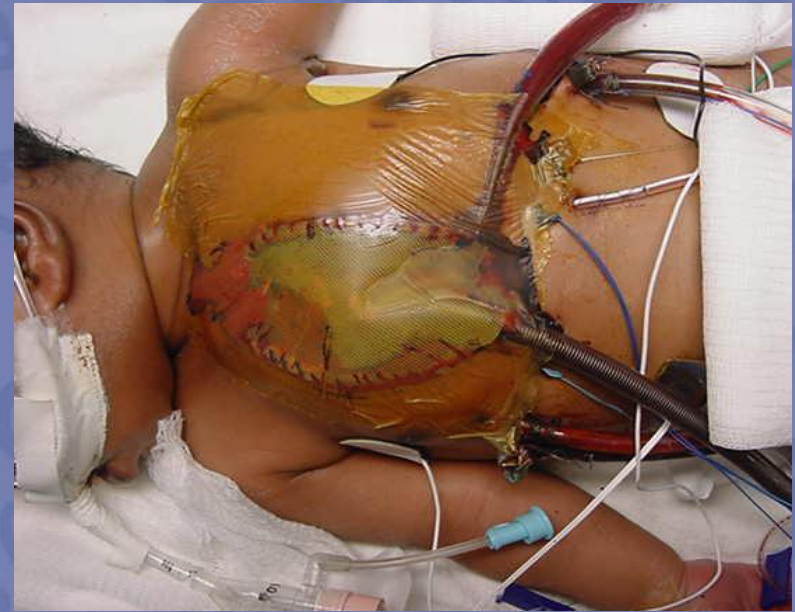


The Revolution™ Centrifugal Blood Pump

- Rotating vane impeller pump blood by centrifugal force
- Volume 57 mls
- Max flow 8 L/min
- Max pressure 800 mmHg
- Low heat generation
- Low hemolysis



ECMO Cannulation Locations



Complications

- Bleeding
- Neurologic – intracranial hemorrhage or infarct
- Hypertension
- Electrolyte imbalances



Transport for Transplant



- CMH received orders for the next day's transport to St Louis Children's Hospital for 3 RBC's, 1 FFP, 1 Platelet Pheresis.
- Blood was requested to be prepared and packed, then picked up by a PICU team member
- Patient #1 had 2 RBCs and a FFP returned to the TSL.
- Patient #2 required 1 RBCs and 1 FFP the rest did go with transport to St Louis.
 - Per Ed in the St Louis lab the RBCs were quarantined and later used for research to "Feed Malaria" the rest was destroyed
- Once the St Louis team (usually 2 doctors, 1 nurse, & 1 perfusionist plus pilot) is ready, the CMH transport team drives the patient (12 to 13 minutes) to the downtown airport. The flight time is about 1 hour and 5 minutes. Space is limited on the plane.



Special Thanks to Eric Smith, Rn, BSN, CCRN, CFRN, C-NPT transportation



Fun Stats

- ✧ Typical time a patient is on ECMO
 - ✧ Neonatal: 7 – 10 days
 - ✧ Cardiac: 3 – 5 days
 - ✧ Diaph. Hernia: 2 – 3 wks
 - ✧ Average time: 7 d (+/- 131hrs)
 - ✧ Median time: 5 d
- ✧ Average number of patients over last 27 years is 23/yr
- ✧ In the last 5 yrs the average up to 34/yr
- ✧ The shortest time on ECMO is 1 hour
- ✧ The longest is 1010 hrs (42 days)
- ✧ The most transfusion to a single ECMO patient was the previous record holder of 1005 hrs... 379 different transfusions.



The Berlin Solution

- Both received Berlin Hearts
 - Ventricular assist device
 - Reabs the body to be in the best shape prior to transplant
- One has survived and is waiting for transplant.



- Thanks to Mary Mahiggin, ECMO nurse coordinator, St Louis Children's



Images by bing



Success rates

Topic for discussion

- ✧ CMH success rates are dependent on underlying diagnosis.
 - ✧ Ave. 30% survival in ECPR patients
 - ✧ Ave. of 95% survival in ECMO patients with Meconium aspiration patients
- ✧ Most around 72% have no handicap at all
- ✧ 17% have some kind of handicap
- ✧ 11% have severe handicaps

A question posed to our director of the pediatric ECMO department Erica Molitor-Kirsch, MD was “Where were the animal ECMO studies?”



Questions ???

